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(D. Black)

Final Report

DEVELOPMENT AND TESTING OF 2-DIMENSIONAL PHOTON COUNTER

Contract NAS2-10618

For period May 12, 1980 to February 12, 1981

ABSTRACT

The two-dimensional photon counter manufactured by Surface Science Laboratories, Inc. has been developed in to a convenient operational system that includes digital recording for field observations. The counter has a bialkali photocathode with a field size of 18 x 18 mm over which it resolves about 100 x 100 pixels and the system records photon positions as 16 bit words at rates up to 14,400 per second. Field tests at observatories have verified the operation of the system as a whole.

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INTRODUCTION

Shortly after the outset of this contract a commercial 2-D photon counter became available to us. As a result we discontinued the development of our own device and concentrated on preparing this commercial counter for speckle imaging of astronomical objects. This commercial device is based on a resistive anode for position sensing and is a product of Surface Science Laboratories, Inc. It had been obtained by Lockheed under Air Force contract F19628-79-C-0183.

Before describing the device a few words concerning the intended application are in order. The problem is to record the faint wavering images presented by large telescopes. At high magnification those images are seen to consist of speckles that agitate as a result of atmospheric turbulence. Television or cinematography are not very suitable at the low light levels because when the frame rate is rapid enough to follow the agitation there may be only a few photons registered on each frame. Under those circumstances a more appropriate procedure is to record a list of the incoming photon coordinates. The list is not only more appropriate for the reason that it is less wasteful than recording mostly the absence of photons on frames, but it also retains more information since the list can always be transformed to frames whereas the reverse is not possible.

At any rate the availability of such a list would permit a variety of a posteriori temporal corrections of wavering images. Specifically we eventually hope to a posteriori correct for the separate wanderings of each spatial frequency component of the image in order to restore diffraction limited sharpness on the atmospherically blurred images.

DEVICE DESCRIPTION

The Surface Science Laboratories photon counter uses a specially constructed image tube that has a 25 mm diameter bialkali photocathode proximity-focused to a tandem set of microchannel plate electron multipliers, in turn proximity-focused to a carefully tailored resistive sheet anode. Each photoelectron from the photocathode ends up generating an event of $\sim 10^6$ electrons impinging on the resistive anode. The

distribution of those electrons among four corner electrodes on the anode characterizes the position of the event. Separate preamplifiers and pulse shapers serve each of the four corner electrodes, and analog ratios of the pulse heights with peak-and-hold circuits indicate in analog form the X-Y coordinates of the events.

Those analog coordinate indications are suitable for immediate display on an ordinary oscilloscope. The presentation is a rasterless form of television and the pictures are readily discernible. Of course the count rate is limited so the technique is only suitable for extremely low light levels and the presentation appears rudimentary in comparison to broadcast television.

Digital coordinate representaions are made available by applying two analog-to-digital converters to the analog signals. The overall scale and timing characteristics of the device are as follows:

256 x 256 digitized field size = 18 x 18 mm
i.e. each digital pixel is 0.07 x 0.07 mm
(Note: Although the digitization is 256 x 256 the effective resolution is only of the order of 100 x 100)
16 μsec dead or dwell time following each event
maximum average count rate ~22,000 events per second.

Figure 1 shows the count rate versus current through an illuminating green LED (Light Emitting Diode).

The image tube has been mounted in an aluminum cannister for convenience. The physical dimensions of the cannister are shown in figure 2.

FIRST FIELD TEST

For the first field test the device was mounted on the 40 cm cassegrain telescope at Stanford Observatory. A narrow band optical filter restricted the light to an 8 Å bandwidth centered at 4936 Å. A variety of stars were observed; a 4 second exposure Polaroid picture of the oscilloscope display on the double star epsilon Lyra indicated roughly the behavior of the photon counter.

RECORDING

The utility of the photon counter is dependent on our ability to record the results. Recording poses a serious problem since the counter furnishes up to about twenty thousand 16 bit numbers per second, and that amounts to a lot of data at a rapid rate. None of our available digital recorders could cope with such data, and virtually all prospective recorders suffered severe shortcomings such as high price, non-portability, and inadequate data rates or capacity.

The possibility of using a Sony Betamax video cassette recorder arose at the suggestion of some Lockheed engineers. The idea is to encode the 16 bits of each word along a horizontal line of a TV raster. TV is easily able to resolve such a 16 column pattern. The pure NTSC (National Television Standards Committee) raster format, with its interlaced fields, is unnecessarily complicated for this digital task and so after appropriate tests we adopted a raster consisting of 240 lines per frame and 60 frames per second, thus providing the capability of 14,400 words per second. The horizontal sweep frequency is 256 times the vertical sweep frequency, with the vertical retrace (vertical sync) occupying 16 horizontal cycles. Each horizontal cycle is divided in to 18 equal intervals as shown in figure 3. The first of those intervals serves for horizontal retrace (horizontal sync). The second interval serves as a porch level, that the recorder uses to set the gain. The remaining intervals are high or low according with the bits of the word being recorded. A 40 word FIFO (First In First Out) shift register acts as a buffer between the asynchronously arriving words and the raster timing, especially during the rather long vertical retrace period. A 16 input data selector performs the parallel to serial conversion.

The average data input rate will of course never exactly match the 14,400 words per second. When the data input rate is higher than that the recorder simply omits occasional words without disrupting those words that are recorded. When the data input rate is lower than that, the recorder fills in by copying the previous word whenever a fresh one is not available.

The overall operation of the recorder functions in a transparent fashion, reproducing the synthetic video signal. A small companion decoder involves a couple of voltage comparators to detect sync and bit levels, a triggerable clock and a SIPO (Serial Input Parallel Output) shift register to restore the original 16 parallel lines plus strobe format suitable for the input port of a computer. A pair of digital-to-analog converters on the decoder permit visual monitoring of the picture playback on an oscilloscope. Once the recording concept and format had been decided upon the hardware implementation proved quick, compact, convenient and inexpensive.

SECOND FIELD TEST

The second field test of the photon counter system at Stanford Observatory included the digital recording system. The optical filter in this second test restricted the bandpass to about 65 Å centered at 4861 Å. This second test demonstrated that the system was both operative and convenient.

Figure 4 shows a star field picture obtained by playing back the video cassette record in to a digital memory operating in multichannel analysis (histogram) mode and then displaying those memory contents on a TV monitor. The picture is composed of 16K photon events. The visual magnitudes and spectral classes of the four brightest stars are 5.3 F0, 8.7 B5, 4.6 B3, 8.0 B5 left to right.

SPECKLE ATTACHMENT

The final hardware ingredient for the speckle imaging project is the telescope adaptor. The requirements are that a highly magnified image be available and finding eyepieces be available for both high and low magnification. The adaptor was designed as a tandem of two almost identical modules, each with its own eyepiece and flip-in mirror. The second module contains a microscope objective to provide the highly magnified images suitable for resolving the image speckles.

With the second module removed the telescope focus falls directly on the photon counter for the case when normal imaging is desired. No provision was made for a de-dispersion prism to compensate the atmospheric dispersion because we always expect to operate with a

narrow-band optical filter.

THIRD FIELD TEST

The third field test, the culmination of this contract, took place 1981 January 12 - 17 on the 1.5 meter telescope at Mount Lemmon. NASA personnel, R. Walker and Y. Pendleton participated in the expedition.

Four vexations hindered the testing. First, only two of the five scheduled nights were clear. Also the nights had below freezing temperatures in the telescope dome, not only presenting considerable discomfort but perhaps adversely affing the operation of the instruments. Second, the count rates behaved rather abnormally in that there were far too many dark counts that tended to pile toward one side of the image field and that the illuminated count rate peaked at less than half its normal maximum. We suspect that due to the cold weather some sort of condensation on the tube socket fouled the electrical signals. After we dismantled the cannister, cleaned it up and restored the normal behavior clouds prevented further observations.

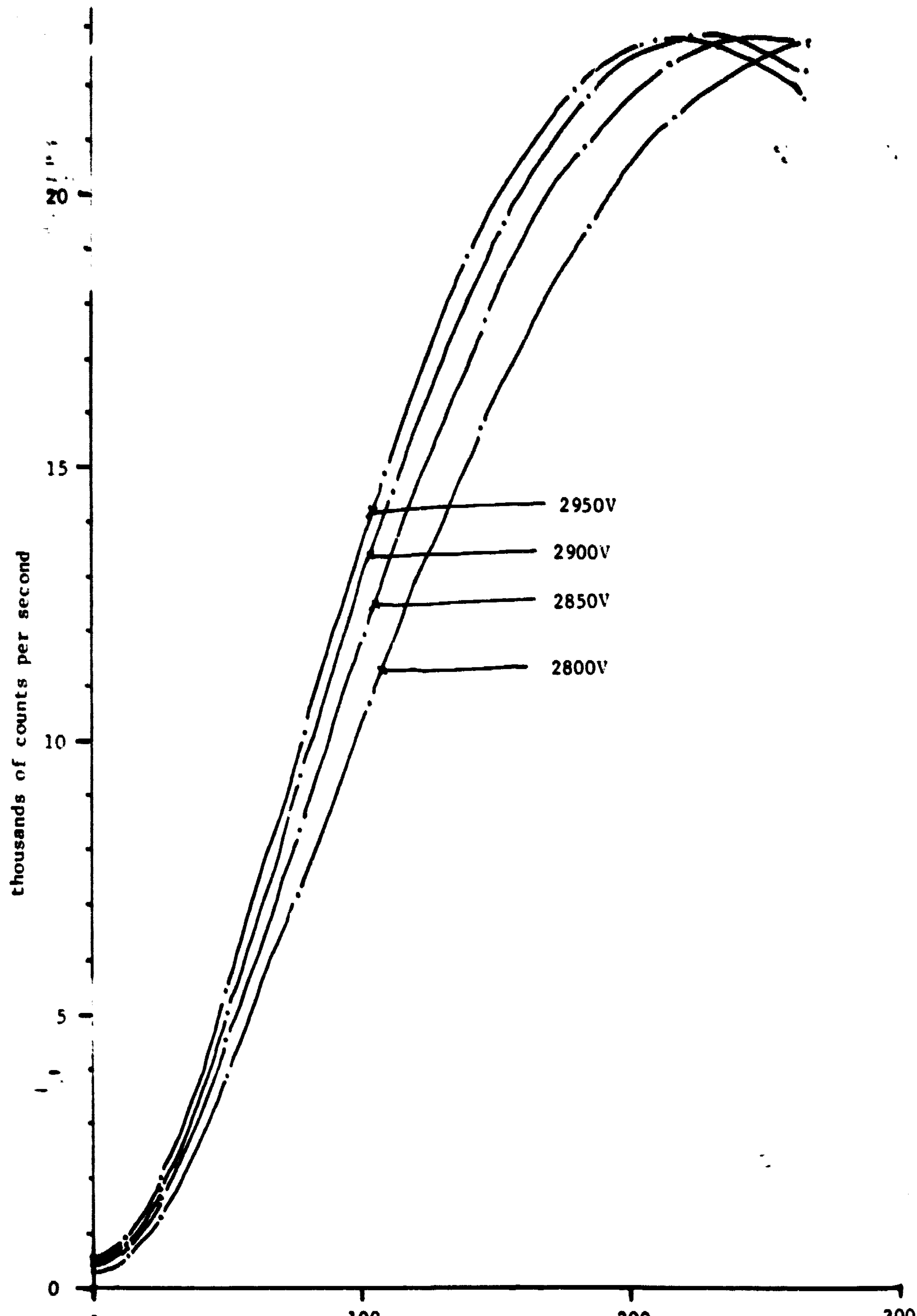
The third hindrance was the poor image quality of the telescope. The circle of confusion was at least 5 arcseconds and was accompanied iwth a large elliptical coma-like halo (even though on-axis) about 10 x 15 arcseconds. The speckles were not really conspicuous in the images. Such quality may be acceptable for infrared work but it unnecessarily handicaps speckle observations. The final hindrance was a tape recorder malfunction that we eventually alleviated by a long cable so that the tape recorder could reside in a warm room. After return from the expedition the tape recorder continued to malfunction even in a comfortable environment.

In spite of the hindrances we managed to gather approximately two hours of observations on various single stars, multiple stars and asteroids. In all cases the narrow band filter was the same as that of the second field test. The diminished sensitivity associated with the abnormal counting behavior prevented observations of globular clusters.

CONCLUSIONS AND RECOMMENDATIONS

The results of the tests indicate that the two-dimensional photon counter system is indeed operational, at least under moderate environmental conditions. After so much effort developing the system we certainly recommend that it be put to use in observational programs. Such use will entail not merely expeditions to observatories, hopefully observing time might be available on relatively local telescopes, but most of the effort will have to be spent on reducing the observations and gaining experience in the manner of data reduction.

Although we have in mind a few observing programs, such as observing the central regions of globular clusters, a closer liaison with practicing astronomers as well as other potential users should be developed to utilize mor fully the existing system.



thousands of counts per second
20
15
10
5
0
2950V
2900V
2850V
2800V
0
100
200
300
LED current microamperes

Figure 1.

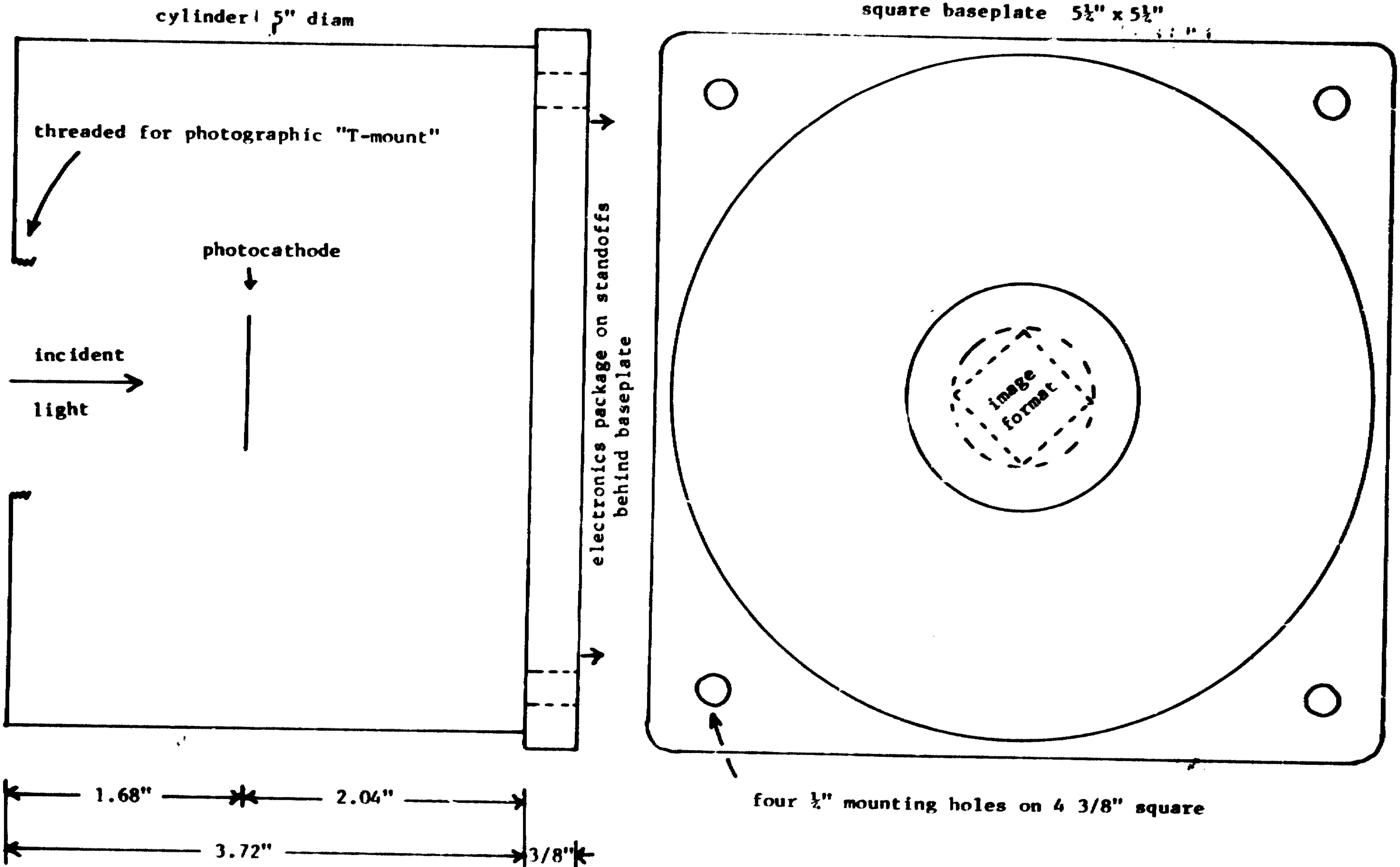
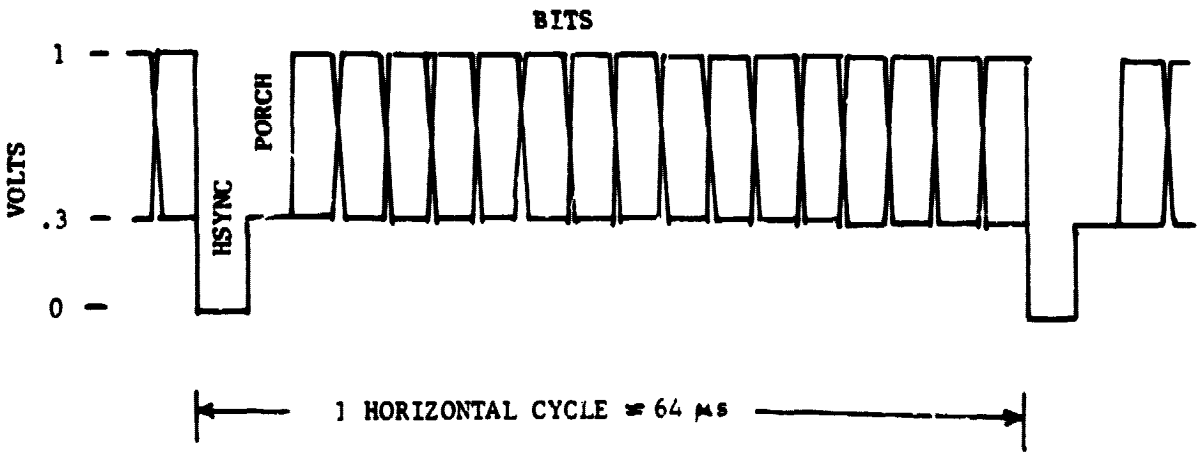


Figure 2. MECHANICAL CONFIGURATION OF PHOTON COUNTER



EVERY 240 HORIZONTAL CYCLES FOLLOWED BY
16 SUBSEQUENT CYCLES AT 0 VOLTS FOR VERTICAL RETRACE.

Figure 3. Recording signal format.

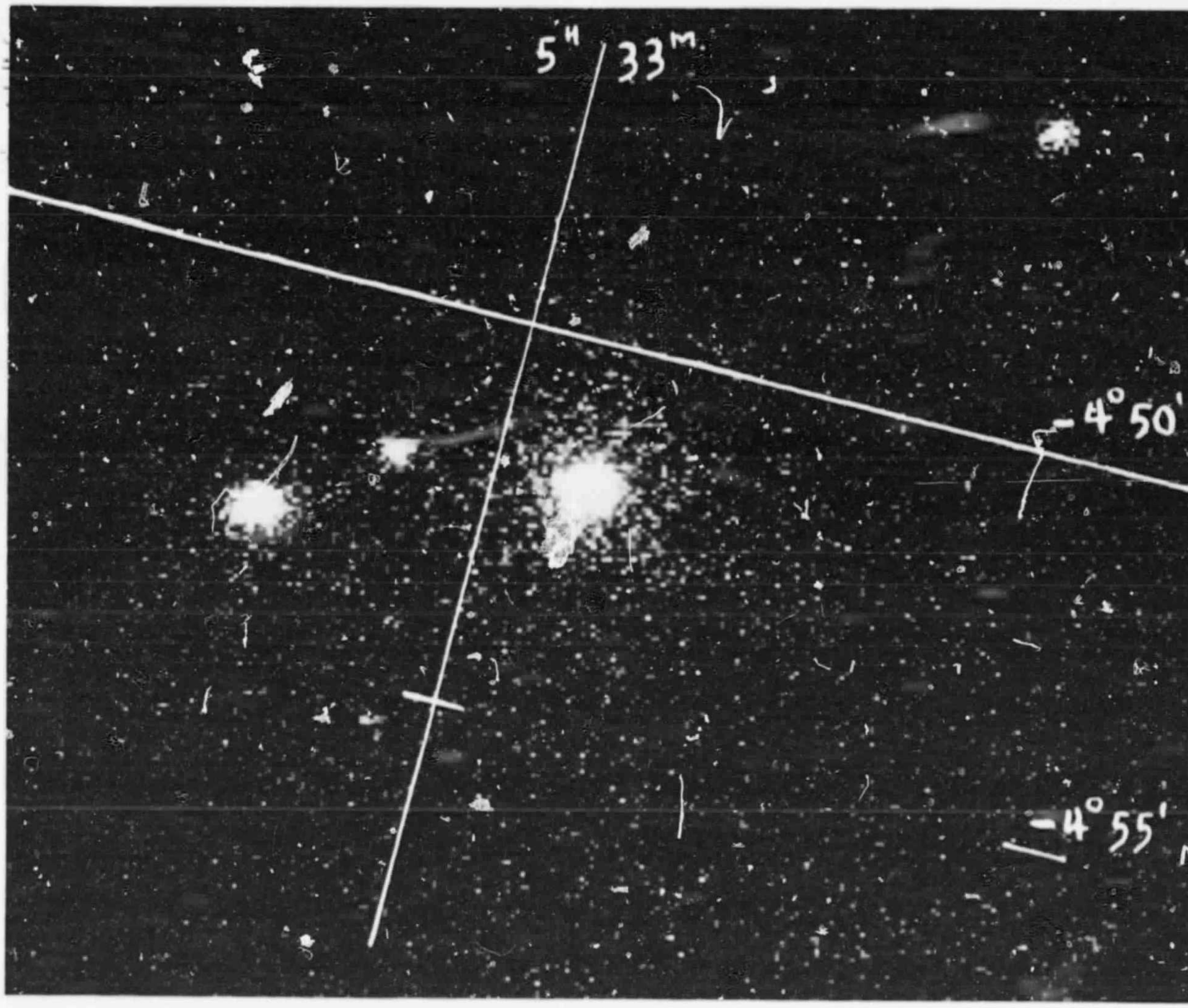


Figure 4. Subsequent TV display of 16K photons recorded during second field test with 40 cm cassegrain telescope. (Reference coordinates have been inked on.)